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Urban Thermal Comfort and Microclimate Design in Public Open Spaces for Social Activities: A Literature Review with Implications for Palembang City, Indonesia

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Abstract. This study presents a structured literature review examining the relationship between urban thermal comfort, microclimate-responsive design, and social activities in public open spaces within tropical cities, with implications for Palembang City, Indonesia. The review synthesizes 31 peer-reviewed journal articles published between 2014 and 2025 retrieved from Scopus, Web of Science, ScienceDirect, and Google Scholar databases. The study applies thematic synthesis to identify dominant microclimatic variables, methodological approaches, and research gaps related to outdoor thermal comfort and public-space use. This paper aims to review and synthesise existing research on urban thermal comfort and microclimate design in outdoor public spaces, with a particular focus on their relationship to social activities, to develop a conceptual framework relevant to Palembang's urban context. The findings indicate that shading strategies, vegetation composition, surface materials, and spatial configuration are key factors influencing perceived thermal comfort and levels of social engagement. Design elements such as tree canopy density, high-albedo surfaces, and appropriate space orientation are shown to reduce heat stress and encourage longer duration and greater intensity of social activities in hot-humid environments. This review highlights the importance of integrating microclimate sensitive design principles into urban planning policies and public open space development to promote thermally comfortable and socially active urban environments in tropical cities.

Keywords: urban thermal comfort, microclimate design, public open space, social activities, palembang city

1. Introduction

Urban environments in tropical regions experience persistent thermal stress due to high air temperatures, intense solar radiation, and high air humidity throughout the year, conditions that are further exacerbated by rapid urbanization and land-use transformation (Gao et al., 2019; Teller et al., 2021). Urban densification, the expansion of impervious surfaces, and the reduction of vegetation cover significantly alter the surface energy balance and increase anthropogenic heat emissions, thereby intensifying the Urban Heat Island (UHI) effect in many tropical cities (Rubel et al., 2021; Hong et al., 2021). As a result, understanding urban microclimate dynamics and their relationship with outdoor thermal comfort has become a central concern in sustainable urban planning and climate-responsive urban design (Verheij et al., 2023). Therefore, examining the relationship between urban microclimate, thermal comfort, and the use of public open spaces is essential to support the development of urban design strategies that are more responsive to tropical climatic conditions.

Urban thermal comfort has therefore emerged as a critical issue in the design and planning of public open spaces, particularly in hot-humid regions where outdoor environments play an essential role in daily social life (Nikolopoulou, 2021). Numerous studies have investigated

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outdoor thermal comfort using indices such as Physiological Equivalent Temperature (PET), Universal Thermal Climate Index (UTCI), and Predicted Mean Vote (PMV), demonstrating that microclimate design variables including vegetation, shading strategies, surface materials, urban geometry, and water features significantly influence local microclimatic conditions and thermal stress mitigation (Elnabawi et al., 2020; Taleghani et al., 2020). The integration of climate-responsive microclimate design strategies in public open spaces is essential to enhance outdoor thermal comfort and support more sustainable and socially active urban environments.

Beyond physical thermal conditions, recent research highlights the importance of human thermal perception and behavioral adaptation in shaping comfort experiences in outdoor environments (Nikolopoulou, 2021; Lyu, 2024). In public open spaces, thermal comfort directly affects how people occupy and experience urban environments, influencing duration of stay, spatial distribution, and types of social activities (Elnabawi et al., 2020). When thermally comfortable conditions are provided, residents tend to engage more actively in communal activities, thereby enhancing social interaction, public health, and urban vitality (Lyu, 2024). This demonstrates that thermally responsive urban spaces can contribute significantly to improving the quality of public life in tropical cities.

However, despite extensive research on urban microclimate and outdoor thermal comfort, the explicit relationship between microclimate responsive design strategies and patterns of social activity in public open spaces remains insufficiently explored, particularly in tropical urban contexts (Kántor et al., 2021; Kurniawan, 2025). Many existing studies prioritize physical and technical parameters, while social use patterns and contextual behavioral factors are often treated as secondary considerations (Mandić et al., 2024). This gap limits the ability of urban designers and planners to translate thermal comfort research into socially responsive and context-specific design strategies.

In tropical countries such as Indonesia, where high temperatures, elevated relative humidity, and limited wind circulation persist throughout the year, outdoor thermal discomfort presents a significant challenge to the usability of public open spaces (Teller et al., 2021). Public perceptions of open space functions ranging from recreational and educational roles to ecological, economic, and social interaction functions play a crucial role in determining how these spaces are used and valued by urban residents (Karina et al., 2017). Consequently, urban open spaces must be understood not only as social and cultural infrastructures, but also as climatic infrastructures capable of moderating microclimatic conditions and mitigating heat stress (Verheij et al., 2023). These issues are particularly relevant in Palembang, where tropical climatic conditions and river-oriented urban development strongly influence the environmental quality and usability of public open spaces.

Palembang City, Indonesia, exemplifies the challenges faced by tropical lowland cities, characterized by persistently high air temperatures, high relative humidity levels, intense solar radiation, and a river-oriented urban morphology that significantly influences local microclimatic conditions (Rubel et al., 2021). Despite ongoing urban development and increasing pressure on green open spaces, empirical studies that integrate microclimate-responsive design, outdoor thermal comfort, and patterns of social activity in Palembang remain limited (Hong et al., 2021; Kurniawan, 2025). This lack of context-specific evidence underscores the need for a systematic synthesis of existing knowledge to inform climate-responsive urban open space design in the city.

Therefore, this study aims to conduct a comprehensive literature review on urban thermal comfort and microclimate design in public open spaces, with a particular focus on their implications for social activities in tropical cities. By synthesizing existing research, this paper seeks to identify key variables, methodological approaches, and research gaps, and to develop a conceptual framework applicable to the urban context of Palembang City, Indonesia. The findings are expected to support evidence-based urban planning and design strategies that enhance thermal comfort, social sustainability, and urban livability in hot-humid tropical environments.

2. Methods

This study adopts a structured narrative literature review approach to synthesize existing research on urban thermal comfort, microclimate-responsive design, and public open spaces supporting social activities in tropical cities (Mandić et al., 2024). A literature review method was selected to identify dominant variables, methodological trends, and research gaps across interdisciplinary studies in urban climatology, architecture, and urban design (Elnabawi et al., 2020).

The initial database search identified approximately 6,800 records related to urban thermal comfort, microclimate design, and public open spaces. After removing duplicates and clearly unrelated studies based on title and abstract screening, around 750 articles were retained for further assessment. Subsequent full-text screening excluded non-journal publications (including conference proceedings, book chapters, and theses), non-English articles, and studies not addressing outdoor environments or public open spaces. An additional inclusion criterion was open-access availability to ensure full methodological transparency and replicability. As a result, 31 peer-reviewed journal articles were selected for in-depth analysis, providing empirical and conceptual insights into the relationships between microclimate-responsive design, outdoor thermal comfort, and social activities in tropical urban contexts, with implications for Palembang City.

A comprehensive literature search was conducted using major academic databases, including Scopus, Web of Science, ScienceDirect, and Google Scholar, which are widely recognized for indexing high-quality peer-reviewed journals in built environment research (Hong et al., 2021). The search process employed combinations of the following keywords: *urban thermal comfort*, *outdoor thermal comfort*, *urban microclimate*, *microclimate design*, *public open space*, *social activities*, *tropical climate*, and *hot-humid climate*.

Boolean operators (AND, OR) were applied to refine the search results and ensure thematic relevance (Mandić et al., 2024).

2.1 Inclusion and Exclusion Criteria

Articles were included in the review if they:
1. Investigated **outdoor or urban thermal comfort**;
2. Examined **microclimate design variables** in public or semi-public urban spaces;
3. Addressed **human perception, behavior, or social activity** in outdoor environments;
4. Were conducted in **tropical, subtropical, or warm-humid climates**;
5. Were published in **peer-reviewed journals between 2014 and 2025**.

Studies focusing exclusively on indoor thermal comfort, building-scale energy performance, or non-peer-reviewed sources were excluded (Hong et al., 2021).

The article selection process consisted of three stages: title and abstract screening, full-text assessment, and final inclusion based on thematic relevance (Mandić et al., 2024). This multi-stage screening ensured that only studies directly addressing the interaction between microclimate design, thermal comfort, and outdoor public space use were retained for analysis (Elnabawi et al., 2020).

Data extracted from each selected study included study location, climatic context, type of public open space, thermal comfort indices used, microclimate variables examined, and social activity indicators (Binarti et al., 2020). A thematic synthesis approach was applied to classify studies into dominant categories and to identify recurring patterns and research gaps (Mandić et al., 2024). The synthesis results informed the development of a conceptual framework relevant to the urban context of Palembang City (Verheij et al., 2023).

3. Discussion

3.1 Characteristics of Reviewed Studies

The reviewed literature predominantly consisted of empirical field studies and simulation-based analyses conducted in tropical and subtropical cities across Southeast Asia, East Asia, the Middle East, and South America (Teller et al., 2021). Public open spaces such as urban parks, plazas, pedestrian streets, and waterfront areas were the most frequently examined spatial typologies (Elnabawi et al., 2020).

Most studies employed quantitative measurement techniques, combining on-site microclimatic data collection with thermal comfort indices such as PET and UTCI (Binarti et al., 2020). Fewer studies incorporated qualitative approaches, including user perception surveys and behavioral observations (Nikolopoulou, 2021).

3.2 Dominant Microclimate Design Variables

Across the reviewed studies, vegetation and tree canopy coverage emerged as the most influential microclimate design variable in reducing air temperature and mean radiant temperature through shading and evapotranspiration (Kántor et al., 2021). Shading devices, both natural and artificial, were consistently shown to enhance thermal comfort during peak solar radiation periods (Taleghani et al., 2020).

Urban geometry, including street orientation and sky view factor (SVF), significantly affected solar exposure and wind flow, thereby influencing outdoor thermal conditions (Emmanuel & Krüger, 2018). Additionally, surface materials with high albedo and permeability were found to reduce heat storage and improve thermal comfort in public spaces (Hong et al., 2021).

3.3 Thermal Comfort Indices and Human Perception

The majority of studies relied on PET and UTCI as objective indicators of outdoor thermal comfort (Binarti et al., 2020). However, discrepancies were frequently observed between calculated comfort indices and users' perceived comfort, particularly in tropical climates where long-term exposure leads to physiological and psychological adaptation (Nikolopoulou, 2021).

Only a limited number of studies explicitly examined the relationship between outdoor thermal comfort and social activities (Elnabawi et al., 2020). Existing evidence suggests that thermally comfortable conditions positively influence duration of stay, spatial concentration of users, and types of social activities in public open spaces (Lyu, 2024). Nevertheless, social activity indicators were often treated as secondary variables rather than central analytical components (Kurniawan, 2025).

3.4 Synthesis and Implications for Palembang City

The reviewed literature collectively confirms that urban thermal comfort in public open spaces is shaped by a complex interaction between microclimatic parameters, urban morphology, and human behavioral responses, rather than by isolated physical variables alone (Aghamolaei et al., 2022; Costa et al., 2024). Comprehensive reviews consistently emphasize air temperature, mean radiant temperature, solar radiation, wind velocity, and humidity as dominant determinants of outdoor thermal comfort, while also highlighting the growing relevance of human perception and adaptation in hot-humid climates (Elnabawi & Hamza, 2020; Nikolopoulou, 2021). These studies demonstrate that thermal comfort in urban spaces is closely linked to both environmental quality and patterns of human activity.

Studies focusing on microclimate design strategies demonstrate that vegetation, green open spaces, shading elements, and surface material choices significantly mitigate thermal stress in tropical urban environments (Ambarwati et al., 2023; Jamei et al., 2020; Taleghani et al., 2020). Empirical evidence from Indonesian cities further confirms that green open spaces function as critical microclimatic modifiers, reducing local temperatures and improving outdoor comfort, particularly during peak daytime conditions (Sari, 2021; Kurniawan, 2025). These findings reinforce the notion that public open spaces should be conceptualized not merely as recreational amenities but as urban climatic infrastructure (Verheij et al., 2023). Overall, the literature indicates that climate-responsive microclimate design is essential for enhancing the thermal performance and long-term sustainability of public open spaces

From an urban morphology perspective, recent studies reveal that street orientation, building density, sky view factor, and settlement form strongly influence microclimatic performance and thermal sensation (Qian et al., 2025; Yola et al., 2025). In river-based and historically layered cities such as Palembang, urban morphology is deeply intertwined with socio-cultural evolution and climatic adaptation processes (Anwar, 2025; Romdhoni, 2020; Azizah et al., 2024). However, despite Palembang's unique river-oriented urban structure, microclimate and thermal comfort studies explicitly addressing this morphology remain scarce.

Beyond environmental performance, a growing body of literature underscores that thermal comfort conditions directly influence social behavior and space-use patterns in public open spaces (Han et al., 2022; Jens & Gregg, 2021). Thermally comfortable environments are consistently associated with longer duration of stay, higher user density, and greater diversity of social activities, thereby strengthening social cohesion and collective urban life (Qi et al., 2024; Lyu, 2024). Nevertheless, these social dimensions are often treated as secondary outcomes, rather than integral components of thermal comfort evaluation frameworks (Mandić et al., 2024). These findings suggest that thermal comfort should be evaluated not only through physical indicators, but also through its influence on human interaction and social activities.

Methodologically, systematic reviews highlight a dominance of quantitative approaches including microclimatic measurements, remote sensing, and simulation-based modeling while qualitative and mixed-method approaches remain underutilized (Ghanad, 2023; Yu & Fang, 2023). Recent scholars advocate for integrated methodologies that combine objective thermal indices with behavioral observation, perception surveys, and spatial analysis to better reflect real-world user experiences (Costa et al., 2024; Liu et al., 2022).

Taken together, the reviewed studies reveal a clear research gap in the integrated analysis of microclimate design, outdoor thermal comfort, and social activity patterns within tropical, river-based urban contexts such as Palembang. While existing literature provides robust evidence on individual components thermal comfort parameters, green infrastructure, or urban morphology there remains a lack of contextualized frameworks that holistically address how these factors interact to shape socially active and thermally comfortable public open spaces in Indonesian cities.

The findings of this study confirm that urban thermal comfort in tropical regions is strongly influenced by the interaction between urban morphology, vegetation coverage, surface materials, shading systems, and ventilation pathways. Previous studies conducted in tropical cities such as Singapore, Kuala Lumpur, Bangkok, and Jakarta demonstrate similar patterns, where vegetation and passive cooling strategies significantly reduce thermal stress in outdoor environments.

For example, research in Singapore by Wong et al. (2011) showed that urban greenery and vertical greening systems can reduce ambient temperatures and improve pedestrian thermal comfort through evapotranspiration and shading effects. Similarly, Yola et al. (2025) found that urban morphology and passive design strategies in Kuala Lumpur influence airflow distribution and solar exposure, directly affecting outdoor thermal comfort levels. In Bangkok, studies by Srivanit and Hokao (2013) indicated that compact urban forms with limited vegetation intensify urban heat accumulation and reduce outdoor comfort during daytime periods. These case studies support the present findings that vegetation density, shading, and urban geometry are among the most influential parameters affecting microclimate performance in tropical cities.

The analysis also reveals that surface material characteristics, particularly albedo and thermal capacity, play an important role in modifying urban thermal conditions. High-albedo and permeable materials reduce heat absorption and surface temperature, thereby mitigating the Urban Heat Island (UHI) effect (Santamouris, 2014). In dense tropical environments such as Palembang, the widespread use of asphalt and concrete surfaces contributes to excessive heat storage and thermal discomfort. Therefore, integrating reflective materials and permeable pavements into urban open spaces can significantly improve thermal performance.

Another important factor influencing thermal comfort is urban geometry and airflow circulation. Street orientation, canyon aspect ratio, and building spacing affect solar penetration and natural ventilation. Oke (1988) explains that optimized height-to-width (H/W) ratios can balance shading and airflow efficiency in urban canyons. Zhou et al. (2025) further demonstrated through ENVI-met simulation that appropriate urban layouts improve thermal comfort by reducing mean radiant temperature (MRT) and increasing ventilation performance in high-density tropical environments.

The relationship between thermal comfort and social activity also emerged as a significant finding. Public spaces with improved thermal conditions supported longer durations of stay, increased pedestrian movement, and more frequent social interaction. This supports Gehl's (2011) argument that environmental quality directly affects public life and urban vitality. Comfortable outdoor spaces encourage users to engage in optional and social activities rather than merely necessary activities.

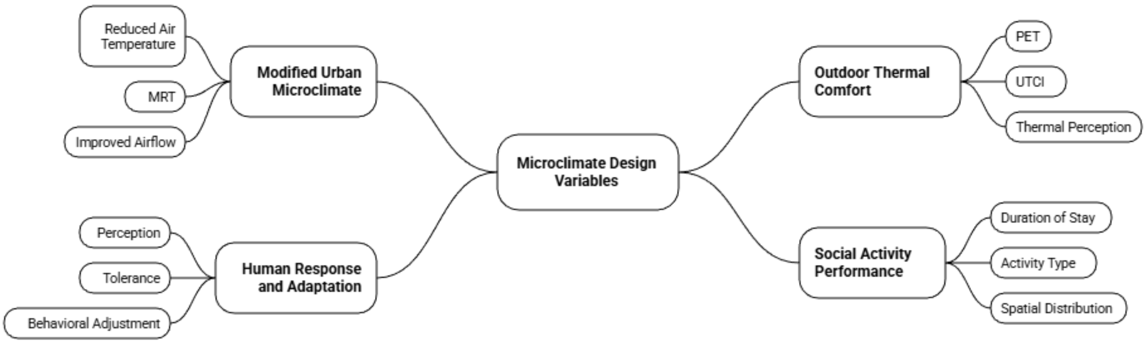

Figure 4.1 Microclimate Design and Social Activity Performance (Author, 2025)

The findings indicate on figure 4.1 that while urban thermal comfort has been extensively studied from a physical and technical perspective, its integration with social activity patterns in public open spaces remains insufficient (Mandić et al., 2024). This disconnect limits the practical application of thermal comfort research in socially responsive urban design (Verheij et al., 2023). This condition highlights the need for a more integrated approach that combines thermal comfort assessment with observations of human behavior and social interaction in public open spaces.

1. Microclimate Performance Analysis

The microclimate performance chart presents the influence of key spatial design variables such as vegetation coverage, shading devices, surface material albedo, and urban geometry on environmental parameters including air temperature (Ta), mean radiant temperature (MRT), humidity, and airflow.

The chart indicates that vegetation and tree canopy density provide the most significant cooling effect. Areas with high canopy coverage exhibit lower air temperatures and reduced MRT due to shading and evapotranspiration processes. Dense vegetation can reduce air temperature by approximately 2–4°C while significantly lowering radiant heat exposure (Bowler et al., 2010; Jamei et al., 2020). The reduction in direct solar radiation creates a more thermally comfortable environment, particularly during peak daytime periods. Similarly, the implementation of high-albedo materials contributes to lower surface temperatures by reflecting a greater proportion of solar radiation, thereby reducing heat storage and minimizing urban heat island effects (Santamouris, 2014). This demonstrates that urban design strategies focused on thermal mitigation are essential for creating more comfortable and sustainable urban environments.

The chart also shows that shading devices, such as canopies, pergolas, and building overhangs, improve thermal comfort by decreasing solar exposure at pedestrian level. Their effectiveness is strongly influenced by orientation and spatial arrangement. In addition, urban geometry and street canyon proportions affect ventilation performance, where optimized height-to-width ratios support airflow circulation while maintaining adequate shading (Yola et al., 2025). This relationship highlights how spatial configuration and passive cooling elements work together to improve microclimatic conditions.

Overall, the chart demonstrates that combining passive cooling strategies produces cumulative cooling benefits and significantly improves outdoor thermal conditions in tropical urban environments (ASEAN Energy Passive Cooling Reports, 2024). Consequently, climate-adaptive urban design approaches can significantly improve environmental quality and public space usability.

2. Social Activity Performance Analysis

The social activity performance chart explains how enhanced thermal comfort affects the intensity and duration of human activities in outdoor public spaces. The findings indicate that spaces with improved microclimatic conditions experience increased levels of pedestrian movement, social interaction, and recreational activities.

Thermally comfortable environments encourage users to remain longer in public spaces. Shaded and vegetated areas, for example, support longer durations of stay compared to exposed hardscape areas. Comfortable thermal conditions also increase the frequency of activities such as sitting, walking, gathering, informal interaction, and community engagement.

The chart further reveals that the relationship between thermal comfort and social activity is positively correlated. As thermal stress decreases, public space utilization increases. Previous studies indicate that improved outdoor thermal comfort can increase public-space occupancy and activity duration by 30–50% in tropical climates. This pattern highlights the importance of climate-responsive design in promoting urban liveability and social sustainability. In tropical cities such as Palembang, where high temperatures and humidity often discourage outdoor activity, microclimate-sensitive interventions can substantially improve the functionality and attractiveness of urban open spaces (Liu et al., 2022).

3. Integrated Interpretation

Together, the charts emphasize that microclimate-responsive urban design is not solely an environmental strategy but also a social one. Design interventions that reduce heat exposure simultaneously improve human comfort, increase public space usability, and strengthen social interaction. The integration of vegetation, shading systems, reflective materials, and ventilation-oriented urban layouts therefore plays a critical role in creating resilient and people-oriented tropical urban environments (Jamei et al., 2020; Zhou et al., 2025).

This gap becomes even more relevant in tropical urban environments, where climatic conditions strongly influence the use and social dynamics of public open spaces. In tropical cities such as Palembang, where high humidity and solar radiation persist year-round, vegetation-based shading strategies appear particularly effective in enhancing outdoor comfort (Rubel et al., 2021). However, the reviewed literature reveals a lack of empirical studies focusing on river-oriented urban morphology, which is a defining characteristic of Palembang (Teller et al., 2021). Therefore, a context-specific understanding of thermal comfort and microclimate design is necessary to support socially responsive urban open space planning in Palembang.

Methodologically, the dominance of objective thermal indices highlights the need for greater integration of subjective perception and behavioral data to better capture user experiences in outdoor spaces (Nikolopoulou, 2021). This integrative approach is essential for developing climate-responsive public spaces that support both environmental comfort and social vitality (Elnabawi et al., 2020). This approach can support the development of more comfortable, adaptive, and socially active urban spaces.

4. Conclusion

This review confirms that urban thermal comfort in tropical public open spaces is shaped by the interaction between vegetation coverage, urban geometry, surface materials, shading systems, and airflow circulation. The findings further demonstrate that thermally comfortable environments significantly influence social behavior, public-space occupancy, and the intensity of social interaction.

The study contributes to the development of an integrated conceptual framework connecting microclimate-responsive design, thermal comfort assessment, and social activity performance within tropical urban contexts. This framework provides theoretical and practical guidance for climate-responsive public open space planning in Palembang and other tropical cities experiencing increasing thermal stress due to rapid urbanization.

Future research should incorporate empirical field measurements, ENVI-met simulations, user perception surveys, and behavioral observations to validate the proposed framework and generate more context-specific urban design recommendations.

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